WIDESPREAD NATURAL INFECTION OF BARBERRY BY *PUCCINIA GRAMINIS* IN TASMANIA.

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(One Text-figure.)

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Synopsis.

Berberis vulgaris was found to be widespread throughout Tasmania and in the summer of 1956-57 showed a high incidence of infection by *P. graminis*. Most of the rust recovered resembled *P. graminis secalis* but *P. graminis tritici* was also recovered. The widespread occurrence of *Agropyron repens* and its marked susceptibility to the variety *secalis* is considered to influence the prevalence of this latter throughout the island.

Introduction.

It has generally been accepted that the alternate host of *Puccinia graminis* Pers. is unimportant in Australia as a source of inoculum each spring and as a medium concerned in the production of new pathogenic strains of this organism. From time to time changes have occurred in the prevalence and distribution of the strains of *Puccinia graminis tritici* E. and H. attacking wheat, but these have been attributed to mutation in the first instance followed by a screening process resulting from the widespread cultivation of wheat varieties having specific genes for resistance (Watson and Waterhouse, 1949; Watson and Singh, 1952; Waterhouse, 1952). Barberries are known to occur, however, and natural infection of them by *P. graminis tritici* has been recorded on one occasion (Waterhouse, 1934). Workers concerned with investigations into the cereal rust problem in New South Wales have had several bushes on the Central Tablelands under observation since 1933, and until 1957 no natural infection had been observed on these bushes.

Evidence for Natural Infection in Tasmania.

During 1956, under the terms of the Colombo Plan, Dr. R. Prasada, of India, was engaged in research at the Faculty of Agriculture, The University of Sydney. In December of that year he visited Hobart, Tasmania, and found within the heart of that city a horticultural specimen of *Berberis* bearing the pycnidial stage of a rust closely resembling *Puccinia graminis*. Following an examination of this material one of us (I.A.W.) corresponded with Dr. G. C. Wade to ascertain the distribution of barberries in Tasmania and the likelihood of their infection by *P. graminis*. Subsequently more infected material bearing old aecidiospores typical of *P. graminis* was forwarded for examination and Dr. Wade stated that barberries were probably very common in certain areas of Tasmania.

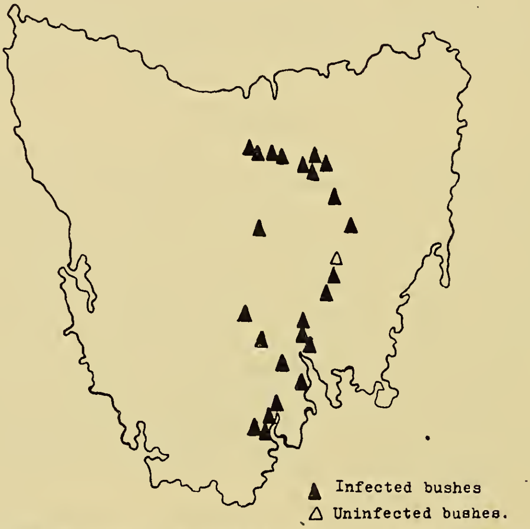
During the latter part of February and early March, 1957, the senior author made an extensive trip through Tasmania to survey the distribution of barberries and to determine the extent to which they were infected. He was accompanied by Mr. Ian Geard, of the Tasmanian Department of Agriculture, whose detailed knowledge of the island was a big factor in the successful location of many bushes.

The map shown in Figure 1 makes clear the widespread distribution of *B. vulgaris*. From the size of the bushes it is apparent that they have been established for many years and in view of the association between large bushes and old buildings it is likely that many of the former were planted more than fifty years ago. It is certain that they are more abundant in Tasmania than in any other part of Australia known to the authors. As shown in the map, a high percentage of the bushes examined were infected.

ASSOCIATION OF UREDIAL HOSTS WITH THE BARBERRY.

Throughout Tasmania *Agropyron repens* (Twitch grass) is widespread as a weed both of cultivation and pasture land. *Agropyron scabrum* also occurs but less abundantly and mainly on pasture land. *Dactylis glomerata, Hordeum leporinum* and *Lolium* sp. are common in the more favoured areas. Rusted plants of four of those grasses mentioned were found in association with infected barberries, the latter were producing aecidiospores, and heavy uredial infection occurred on the grasses. Rye grass (*Lolium* sp.), although found with barberry on many occasions, was not infected by rust. However, in Launceston, a patch of rusted Rye grass was found well removed from barberry. The organism responsible was *P. graminis lolii.*

Agropyron repens is the species that contributes most teleutospore material for spring infection of barberries. This is inevitable since many of the bushes are to be found in home gardens where, under proper care, they make attractive specimens. Should the gardens become neglected, however, even for short periods, *A. repens* develops rapidly and spreads by a rhizomatous type of growth. In moist seasons, such as 1955-56, the host plants are well placed for reciprocal infection to occur when the rusted grass is growing up into the barberry. Despite the dry summer of 1956-57 evidence for a complete cycle of events was obtained. At Oatlands and Middle Park old teleutospores formed during the 1955-56 season were found on *Hordeum leporinum, Agropyron scabrum* and *A. repens.* The infected barberries growing in association were producing aecidiospores resulting from the initial infection in the spring of 1956. Uredospores on *Hordeum leporinum* and *A. repens* probably resulting in part at least from the aecidiospore infections and teleutospores on this same host, indicated that the cycle had been completed for another year.



Text-fig. 1.—Map of Tasmania showing the distribution of Barberries found on the survey.

GLASSHOUSE TESTS WITH AECIDIAL AND UREDIAL MATERIAL.

In view of the close association between the uredial and aecidial hosts throughout the area surveyed, an attempt was made to relate the strains isolated from both hosts at any one collecting point. This was not entirely successful, as many aecidial collections proved non-viable. In Table 1 is shown a classified list of the localities where barberries were found; it indicates whether infection was observed, and also shows the incidence of rust on the uredial host growing in association.

Since the variety of *P. graminis* responsible for the barberry infections was not known, spores from the field collections of both aecidial and uredial material were placed onto seedlings of wheat, oats, barley, rye and *Lolium perenne.* Two aecidial and twelve uredial cultures were established on Black Winter Rye and on an unnamed barley variety B125. This latter is used extensively for glasshouse tests, since it is susceptible to both *P. graminis tritici* and *P. graminis secalis* E. and H. and reacts with a 2+ to 2‡ type of infection. Algerian oats were resistant to all 14 collections but susceptible to those taken on *D. glomerata* which in each case were of *P. graminis avenae* E. and H. Federation was resistant to all 14 collections with a type 2= and 2 reaction.

TABLE 1.

Location of Barberries in Tasmania and Evidence for Infection on Them and Associated Grasses.

Locality.	Infection on		Locality.	Infection on	
	Barberry.	Grass.		Barberry.	Grass.
Hobart (Botanic Gardens)	+	+[1]	Evandale	+	–
Huonville (Longley Grove)	+	+[1]	Perth	++	+[3]
Kermandie	+	–	Perth	+	+[1]+
Castle Forbes Bay ..	+	–	Longford	+	–
Franklin	++	+[1]	Longford House	+	–
Ranelagh	+	–	Hagley	++	++[1, 2]
Bagdad	+	+[2]	Westbury	+	++[1]
North Bagdad	+	–	East Deloraine	+	–
Kempton	+	–	Deloraine	+	+[1]
Oatlands	++	++[1, 3]	Penstock Lagoon ..	+	+[1]
Middle Park	+	+[1, 4]	Ouse	+	++[1, 3]
Tunbridge	–	–	Hayes	+	+[1, 3]
Campbell Town	+	+[1, 3]	New Norfolk	+	+[1]
Youngtown	+	+[2]			

+, light infection ; ++, heavy infection ; –, no infection.

[1] *Agropyron repens ;* [2] *Dactylis glomerata ;* [3] *Hordeum leporinum ;* [4] *Agropyron scabrum.*

The infection types on the cereals and grasses studied indicated that the various collections were mostly of a rust that agreed closely with *P. graminis secalis.* It was apparent, however, when a side-by-side comparison of the resulting cultures was made on a number of selected wheat varieties, that at least four strains of the fungus could be distinguished. Little Club was the variety most useful for the differentiation of the strains as shown in Table 2. No attempt was made to compare these reactions with those of overseas collections and the culture of *P. graminis secalis* isolated previously in Australia (Waterhouse, 1957) was not available for comparison. Numbers assigned to the strains have no relationship to similar numbers given to overseas strains.

TABLE 2.

Reaction of Certain Cereals and Grasses to Four Strains of P. graminis secalis.[5]

	Strain.			
	1	2	3	4
Wheat, Little Club	0	1, 2=, 2–	2	2‡, 3
Oats, Algerian	0	0	0	0
Barley, B125	2‡	2‡	2‡	2‡
Rye, Black Winter	3+	3+	3+	3+
Rye grass, *L. perenne* ..	0	0	0	0

[5] Since the completion of this paper collections of rust from infected barberries from Tasmania have yielded strains of *P. graminins tritici.*

Table 3 shows the distribution of the strains throughout the island and it is apparent that strains 2 and 3 are the most prevalent.

All of those listed in Table 2 were collected on grasses. The aecidial cultures both proved to be strain 2 and came from "Quamby Plains", Hagley and from Penshock Lagoon. Uredial material collected at each of these two places failed to germinate.

Representative cultures of three of the four strains were used to inoculate more than 40 wheat varieties but none proved as susceptible as Little Club. Strain 4, which is the most virulent on Little Club, also gave high reactions on the average on the other varieties but they could not be used for differentiation purposes.

Two of the collections made from *A. repens* proved to be mixtures of *P. graminis tritici* and *P. graminis secalis*. Each was taken in a home garden at Oatlands, where barberries were heavily infected. The mixtures proved to be of *P. graminis secalis* strain 3 and *P. graminis tritici* strain 21Anz-1. These were the only occasions on which a strain of wheat stem rust was found in association with barberry. 21Anz-1 was also isolated from a commercial wheat field well removed from the alternate host at the time of making this survey.

TABLE 3.

Distribution of Four Strains of P. graminis secalis *in Tasmania.*

Strain.	Localities where Found.
1	Middle Park.
2	Hobart (Botanic Gardens), Campbell Town, Perth, New Norfolk, Ouse.
3	Hobart (Botanic Gardens), Huonville (Longley Grove), Oatlands, Westbury.
4	Hagley (St. Mary's Manse).

SIGNIFICANCE OF THE BARBERRY INFECTIONS.

The significance of susceptible barberries in promoting a diversity of pathogenic strains of *P. graminis* is so well known that no further emphasis is needed. In Australia the presence of relatively few strains of *P. graminis tritici* has been attributed to the sparse distribution of susceptible species of barberry (Waterhouse, 1952). While this is still true for the wheat belt, the present results show that in Tasmania susceptible barberries are widespread throughout the island and under certain circumstances infection by *P. graminis* is very common. The climate on the island is particularly favourable for infection. Teleutospores are produced under relatively cool conditions and, unlike those produced in the mainland wheat belt, they can retain their viability through the winter for a spring infection. On *A. repens* teleutospores are produced right through the summer and those formed in late autumn have not been exposed to high temperatures.

Certain areas of the mainland provide a similar environment, particularly the tableland districts of New South Wales and the more elevated parts of southern Victoria. However, susceptible perennial grasses comparable with *A. repens* are not common in these areas and the teleutospores are seldom brought into close proximity with susceptible bushes, although *A. scabrum* was associated with barberries at Yetholme in 1933 (Waterhouse, 1934). The most likely association would be between *Lolium perenne* and the alternate host. In March, 1957, infected barberries were found in New South Wales for the first time since 1933. These occurred at Meadow Flat. Heavily rusted plants of *Lolium perenne* growing below were carrying both uredospores and teleutospores of *P. graminis lolii.* This same variety probably caused the infection on barberry but the aecidiospores failed to germinate.

Varieties other than *P. graminis tritici* have been mainly recovered in the collections reported herein and this fact would appear to lessen the menace of barberries in Tasmania. Waterhouse (1957) has already reported the presence of *P. graminis secalis* on the mainland and it has not become important. Rye is not grown to any extent in Australia and barley usually matures before the temperatures are high enough for stem rust to become established. *A. repens* is so widespread on the island and so susceptible to *P. graminis secalis* that it is inevitable that this latter should predominate in this area. But *A. scabrum* and *Hordeum leporinum* are also commonly associated with barberry and it is well known that these species are both susceptible to the variety *tritici* (Waterhouse, 1929, 1952). With such congenial hosts available there is always a possibility that infections with this variety will occur. It was, in fact, recovered from grasses in two of the collections made and each proved to be 21Anz-1. Although little wheat is grown in Tasmania, strains from barberry with new gene combinations and showing high survival ability would readily become established. There is circumstantial evidence for spore movement across Bass Strait so that once a strain predominated in Tasmania it would soon be carried to the mainland.

There is also some evidence to suggest that in recent years barberries have become significant in changing the dominant rust flora in eastern Australia. The isolation of strain 21Anz-1 in 1954 from the south-eastern areas of the country and its rapid rise to become the dominant strain in southern New South Wales, Victoria and Tasmania in 1955 (Watson, 1955, 1957*a*) suggests that it first originated in the south. As it differs so markedly from the prevalent strains that occurred between 1928 and 1953 it is unlikely that it arose by mutation. Apart from its ability to attack Celebration, a variety not widely grown in the area, it shows no genes for virulence not present in strains prevailing earlier. The phenomenal rate of spread suggests a manifestation of heterosis resulting from a hybridization process which has brought together several dominant factors associated with the high survival ability shown by this strain. In 21Anz-1 certain of these have been for virulence and one at least for avirulence. More detail will be given to this matter in another publication now in preparation.

The recovery of strain 21Anz-1 from two of the collections raised the question of biotypes of *Agropyron repens*. It is possible that certain clones are susceptible to the variety *tritici* as well as to the variety *secalis*. Repeated inoculations with several strains of the variety *tritici* revealed no susceptibility to any of them, but all were susceptible to *P. graminis secalis*. The occurrence of plants of this species or any other species with the double susceptibility to the variety *secalis* and the variety *tritici* would present further possibilities for genetic recombination of virulence genes to occur. While it has not yet been demonstrated that dicaryons of *P. graminis secalis* and *P. graminis tritici* will undergo somatic hybridization that possibility suggests itself from the work of Watson (1957*b*). In these studies an avirulent strain of the variety *tritici*, not unlike *P. graminis secalis*, hybridized readily on wheat seedlings with a virulent strain of the variety *tritici* to give strains much more virulent than either parent. Further experiments are being carried out on this matter and will be published elsewhere, but already they emphasize that the degree of virulence that can result from crossing relatively avirulent and genetically unknown dicaryons on wheat plants cannot be predicted.

Whatever the mode of variability of *P. graminis*, barberries will always continue to be a menace to cereal crops while they provide the efficient means to assemble and reassemble particular gene combinations which are then free to mutate or undergo somatic hybridization to even greater virulence. From this point of view the significance of the infections in Tasmania should not be underestimated.

Acknowledgements.

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